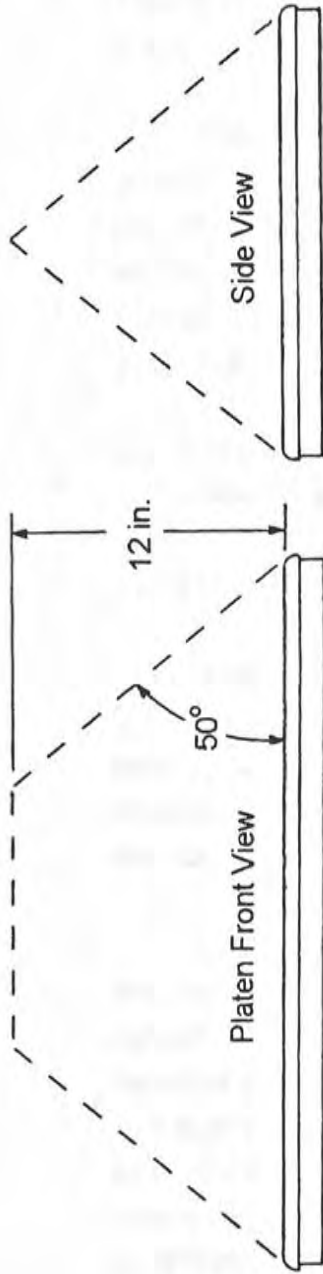


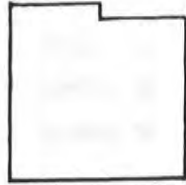
# I3Detroit Proto-Form Vacuum Forming Machine Operation

## Maximum Size

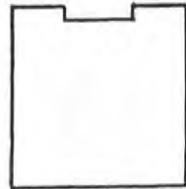
Your Pattern should fit inside the dotted lines



X



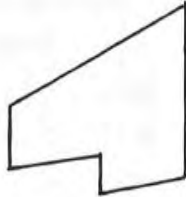
X



OK



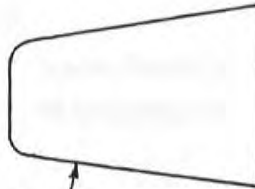
OK



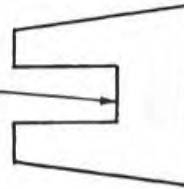
## Undercuts

Your pattern should always be wider at the bottom

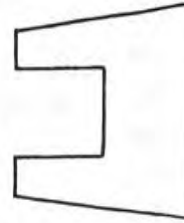
Too Tall



Too Deep



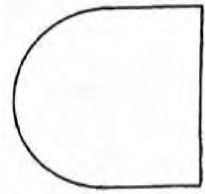
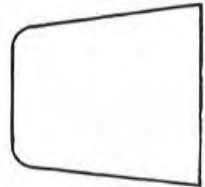
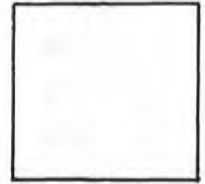
OK



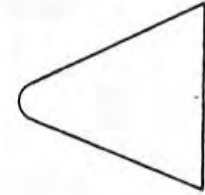
## 1 to 1 Ratio

Your pattern or cavity should be no taller than it is wide

Hard



Easy



## Avoid Vertical Sides

Tapered sides and rounded corners are better

## Vacuum Forming Limitations

----- Your pattern should not have undercuts. These are areas where the plastic can wrap around or under the pattern in such a way that you can't remove the formed part.

----- The plastic will shrink as it cools. This shrinkage is in the range of .005 to .008 in. per inch. This can be as much as 3/8 inch. on a 4 foot part. If you can't tolerate this then you must make the pattern oversize.

----- You should always provide a slight angle on vertical sides of your pattern. This is called "Draft" angle and should be around 3 to 5 degrees per side. The reason for this is the shrinkage mentioned above. Imagine forming over a cube with straight sides and having the plastic shrink 1/8 inch as it cools. You can imagine that it will grip the pattern very tightly. If you have tapered sides then it will come off more easily.

----- The wall thickness will not be uniform on a finished part. The plastic will be the thickest where it first touches the pattern and the last part to touch will be the thinnest. The amount of thinning depends entirely on how much the plastic has to stretch.

----- There is a general rule of thumb that the pattern shouldn't be taller than it is wide. This can result in webbing (wrinkles) in the plastic usually coming from a tall corner, as well as excessive thinning of the plastic. This depends a lot on the shape of the pattern with rounded shapes being better than square shapes.

Look at any vacuum formed parts that you can find and you will see that they follow these simple rules. Despite these limitations there are millions of uses for vacuum forming. Perhaps the greatest advantage to this versatile process is the low tooling costs for the pattern. To make a 12 x 12 inch part with injection molding you would have to spend around \$20,000 for a tool and wait 8 to 12 weeks. With vacuum forming you can make a simple wood pattern for a couple of dollars, Or a permanent epoxy pattern for around \$50.00, all in an afternoon.

## Introduction

You can vacuum form a wide variety of plastics, as long as they get soft when their hot. These are called thermoplastics and include the common ones listed below as well as others:

<b>ABS</b>	<b>Acrylic</b>	<b>Polyethelene</b>
<b>PVC</b>	<b>Styrene</b>	<b>Polypropylene</b>
<b>Polycarbonate</b>	<b>Butyrate</b>	<b>PET-G</b>

If you are not sure of the suitability of a particular part for vacuum forming, you can show it to a commercial vacuum forming company for their opinion. After a while you will develop a feel for what can and can't be done.

## Steps for using the Proto-form Vacuum Former at i3Detroit

1. Verify the 220v and the 110v power cords are plugged in.
2. Turn on the oven breaker switch at the rear electrical box.
3. Close the main valve that is on the right side of the front panel. The yellow handle should be vertical.
4. Set the lower valve to "tank".
5. Switch on the vacuum pump. Let the pump run until the tank gauge reads 22 inHg.
6. Set the lower valve to platen.
7. Use the lift bar to slightly raise the carrier frame.
8. Place a 2 or 3 inch spacer below the carrier frame so it cannot be lowered completely.
9. Remove any binder clips and insert your 2x2 plastic between the upper and lower carrier frames.
10. Replace binder clips to hold plastic in carrier frame.
11. Raise the lift bar so the carrier frame travels all the way to the oven.
12. Turn on the oven switch(s). For 2x2 only turn on the center oven. For 2x3 turn on both the center and outer oven switches. Do not leave the vacuum former while the oven is on.
13. Gently set your buck (mold) onto the platen surface. Do not use anything that is hollow on the bottom. It will be crushed by the vacuum and platen damage is likely to occur.
14. Monitor your plastic as it is heated by the oven. It will wrinkle, shrink and then start to sag. Glove use is recommended due to hot plastic and carrier frame.
15. Lower the lift bar and quickly open the main valve by pushing the lever to the left. Keep the valve open for 1 second and then close it.
16. Since the vacuum pump is still running and the lower valve is set to platen, your project will receive the maximum vacuum the pump can create.
17. Shut off the pump after a few seconds. While wearing gloves, release the warm or hot binder clips.
18. Remove plastic from the carrier frame.
19. Turn off the rear oven breakers and make sure the carrier frame is still lowered. Do not store the carrier frame in the raised position.
20. Unplug the 110v power cord.
21. Clean any mess you have made.

## Chapter 11

### Operation

#### *Congratulations !*

Stand back for a minute to admire your work, then treat yourself to a nice dinner. By building this yourself, you just saved enough money to for a Caribbean cruise and a used car. When you get back let's try this thing out.

#### Machine Operation

Lets go through the process step by step to make a typical part, the whole cycle will only take a few minutes.

#### **Get Set Up**

Pick an easy plastic such as styrene for your first try and find a suitable test pattern. Avoid undercuts and read the forming tips at the end of this section for other mold related ideas.

Operate the machine in a warm room with adequate ventilation and avoid drafts that could cause uneven heating. The machine should have at least 18 inches of clearance all around and 36 inches of clearance on top. Make sure nothing is covering the top vents and there are no flammable liquids near by. With 5 -10.000 watts of heating going on, you should always have a fire extinguisher handy.

Plug one or two ordinary house fans into the outlet box in back and set them on a workbench or table at the right height so they blow across the platen. The fans will operate from a switch on the front panel.

#### **Evacuate the tank**

Close the main valve and pump down the tank as far as you want, then turn the pump off. It should hold this vacuum and is now in stand by mode.



**Pre - Heat the oven** - Turn on the main oven switch, then raise the clamp frame up to trip the micro switch and turn the oven on. The elements will get warm and heat up the metal oven box and clamp frame. This warm up period should only take two or three minutes. Do not exceed five minutes without a plastic sheet in place because the lower carrier frame glides are exposed directly to the heat and could melt. Get your plastic sheet and pattern ready while you are waiting.

you can leave your pattern on the platen during this time to warm it up if needed. Some molds such as plaster and metal have a lot of thermal mass and need to be warmed up so they don't cool the plastic before it is formed.

### **Important**

***Do Not*** use this machine to dry out plaster molds, cure epoxy, get a sun tan or anything else that requires the oven to be on for an extended period. The oven is very intense and is designed to be used in cycles, on for a few minutes then off between parts. See the note on heat management at the end of this manual.

### **Load the Plastic**

Lower the carrier frame and put your plastic sheet between the clamp frames. Secure it with binder clips or toggle clamps. Use gloves because the metal parts will be warm. The micro switch turned the oven off when you lowered it, so load the sheet fairly quickly before the oven cools down too much. Raise the handle again to turn the oven on and start the heating cycle.

### **Heating the Plastic**

***Watch the plastic as it heats.*** Do not walk away or answer the phone, because some plastics heat very fast. You want to watch for it to start sagging in the middle. It will first expand and bulge downward, then it will get wavy and finally pull tight as it gets soft. After this point you can expect it to start sagging.

Some plastics sag fast and will go all the way to the platen if you let them, others are very reluctant to sag and behave more like a rubber sheet.

You can poke at it with your finger to test its softness. Let it sag far enough to approximate the volume of your pattern, but if you go too far it will form wrinkles or webs in the finished part. If left too long the plastic can burn and possibly ignite.

**Remember... Never take your eyes off the oven while it is on!**

It is easy to sight across the bottom of the clamp frame and see the sag. You can attach a ruler to the back of the wood box for visual reference, but in a short time you will quickly develop a feel for when the plastic is ready. I encourage you to keep a notebook of your results so the next time will be easier.

### **Forming**

Your plastic is soft, the vacuum tank is charged and all that's left is the fun part. By now there is probably a crowd standing around, so tell them not to blink because this happens fast.

In one smooth motion lower the handle and push down to stretch the plastic over your pattern. You won't have to push very hard, but make sure it is bottomed out as you reach down and quickly open the valve... I told you it was fast. Keep light pressure downward and turn on the fans. The plastic cools very quickly, you can poke it with your fingers to see when the corners get firm so you can't make a dent with your finger nail.

Close the vacuum valve and let the pressure bleed down. Remove the clamps and take out the finished part, the pattern will most likely come with it. You will have to flex the plastic, tap on it and occasionally scream and yell to get the pattern to fall out.

### **Repeat the Cycle**

If you are doing another part, load a new sheet and raise the handle to start heating again. Recharge the vacuum tank if needed and put your pattern in place for another try.

### **Shutting Down the Machine**

When you are done, shut off the main oven switch and lower the carrier frame. This disables the oven in two ways, so even if the switch is



bumped, the oven won't turn on until the handle is fully raised. As a last safeguard the pilot light will come on to warn that it will get hot.

If you are using an automatic switch for the pump , be sure to turn off the manual switch to disable it so it won't cycle on and off if it develops a leak. The pilot light should indicate when the pump has power.

### Heat Management

If you are just doing a few parts, then heat build up is not a concern, but if you are going to make parts all day long then you should have a strategy to cope with it. Never forget that you are unleashing a lot of energy when the oven is turned on. This would be comparable to running an arc welder continuously. Aside from the obvious high cost of electricity, there are other reasons to use the oven Only during that part of the cycle when it is actually needed.

When a plastic sheet is in the clamp frame, it acts as a shield by absorbing the heat into itself and protecting everything below it. That's why we limit our warm-up times ( without plastic) to 2 or 3 minutes With out that shield the intense heat could possibly melt the plastic glides or cause other damage. If you leave the oven on between parts while you are doing other things, Your pattern and even the machine itself has to absorb all that heat. Although it is not healthy, it is unlikely to cause immediate damage to the machine but your pattern may not fare as well.

A wood or epoxy pattern will survive many forming cycles, but if you let it bake unprotected it can be damaged. metal is the only material that is not affected to some degree by excessive heat. By having the oven turn off, when the plastic is lowered and using fans, we not only save a lot of electricity but we protect the pattern and machine from long term damage.

***Remember...*** *The oven is not meant for continuous use. Under normal operation, it is never on for more than about 5 minutes and it is off during the forming cycle. Do not use this machine for any other use that requires the oven to run continuously.*

## Safety Considerations

I won't bore you with this section, I tried to mix the safety messages in throughout the manual so you wouldn't notice them, but I am almost done now and here are a few more worth mentioning.

- Always wear safety glasses when reading this manual... I just wanted to see if you were paying attention.
- Never operate this machine in the bath tub.. Ok now I'm sure.
- Some plastics give off toxic fumes, especially when they are over heated. Ask you plastic distributor if there is any thing to worry about when you buy the plastic. They are required to supply you with material safety data sheets on request.
- Keep an appropriate fire extinguisher handy just in case..
- Find out where the main power disconnect is that supplies your machine. If there is any emergency, shut off the power.
- Never leave the machine when the oven is operating, I know I said this before, but its important.
- Use pilot lights on the vacuum and oven circuits so you remember to turn them off when you are done.
- Use a minimum clearance to combustibles of 18 inches on all sides and 36 inches above. Never set anything on top of the oven or block the vents.
- Don't Micro-wave your cat, I was just kidding when I said that.

## Forming Tips

Vacuum forming is very easy and you should be making successful parts right away, but there are some limitations as described in the introduction to this manual. There are also some common mistakes that can be avoided if you follow these tips.

**Webbing** - This is where the plastic folds together and forms creases. It is usually caused by over stretching the plastic (too much sag), but the shape of your mold may also be a factor. The general rule of thumb is that your pattern should be no higher than it is wide, but shapes with vertical sides and square corners are more prone to webbing than ones with tapered sides and rounder corners. Webs can also occur when multiple patterns are placed too close together. Here are some general tips to prevent webbing:

- Try less sag before forming, this creates more tension in the plastic sheet.
- Thicker plastics will have less tendency to web than thinner sheets.
- Place scrap blocks of wood on either side of the area that is webbing, by varying the size and position of the blocks you can usually cause the web to flatten out or at least trick it into webbing off your scraps instead of your pattern.
- Modify the mold into a friendlier shape for vacuum forming.

**Avoid hollow molds** - The air space under a hollow mold adds extra volume that must be evacuated, this can result in an excessive vacuum loss by the time the plastic gets pulled down. Hollow molds may also collapse or damage the machine. For example, say you have a steel pan and you want to vacuum form over it to make some storage bins. If the pan

measures 18 x 18 x 6, that's 1,944 cubic inches of air to evacuate which will take way too long.

Now here's the scary part, The inside of the pan has 756 square inches of surface area, so if you can pull a 27 in. hg. vacuum ( equal to 13 psi), this will result in over 9800 lbs. of force trying to pull the pan down to the platen. You Will collapse the pan and most likely destroy the platen. Remember how long it took to drill those holes?

Now this is an extreme example, and you can get away with a hollow mold if it is small and very sturdy, but it should have ribs or bracing so it doesn't hurt the platen. It would still be best to back fill it with something like plaster or concrete.

**No Undercuts** - This one should be common sense, but it is amazing how many people can't recognize this problem. An undercut is an area of the pattern that lets the plastic wrap around or suck under it in such a way that you can't remove the pattern. Imagine forming over a ball and trying to remove it afterwards.. you can't. You can sometimes beat this problem by using a soft rubber pattern and pulling it out, or in more severe cases by using a firm rubber shell over a hard core and pulling the core out first.

**Don't paint your pattern** - You may get a strong urge to seal your wood or plaster pattern with paint or varnish, but don't do it. These coatings can get sticky when hot and they sometimes blister and peel. If you want to fill in the wood grain and make your patterns last longer, use ordinary polyester resin as used for fiberglass. It will take several coats and lots of sanding to fill the wood grain and put a hard coat on your pattern. Epoxy resin does not fill as well and often causes sticking.

a polyester resin shell will hold up OK, but its a lot of work. If you are just making a few parts, use the plastic shell trick described below. If you need to make many parts make an epoxy resin mold as described under "Cloning your pattern".

**Put a plastic shell on your pattern** - This works great on clear parts or any time the plastic is picking up texture from your wood or plaster pattern. Form a sheet of styrene over it first, then trim it out and leave the styrene

part on your pattern while you form the other plastic over it. Don't use any kind of mold release unless the two stick to each other (they usually won't)

You could even do this over a bare wood mold, because the styrene will block the wood grain from showing through. and you could easily wet sand it to remove any that does show.

**Clone your pattern** - This is one of my favorite tricks. Lets say you made a great little hand carved pattern for a slot car body, but you want to form 30 at a time and you don't feel like carving 29 more patterns. Vacuum form one high definition part from your hand carved pattern. By this I mean use a thin sheet of plastic that forms easily such as Styrene and use maximum vacuum so it forms crisp detail.

Now use this part to cast duplicate patterns from epoxy resin. Save the original wood pattern as a master and use the copies for production. Sources for epoxy resins are at the end of this chapter.

**Vent your patterns** - This means to drill small holes in all blind pockets or corners where the vacuum can't reach from the platen. You don't need to make swiss cheese out of it, just a few 1/32 holes in all the low spots. If you are trapping air on the surfaces see below.

**Don't polish the mold** - This applies to all mold materials. If you make it too smooth, air will get trapped on the surface when the plastic seals to it. You really want a very fine texture or scratch pattern that lets the trapped air get sucked out. Use 400 grit for normal use and 600 grit for clear parts to minimize show through.

**Taper the sides** - This is called a draft angle and should be at least 2 degrees or preferably more for easy pattern removal. The plastic shrinks a lot and tries to grip the pattern, if the sides are tapered it just comes off easier.

**No mold release** - Unless you need it.. Many people smear their patterns with Vaseline or cover them with talcum powder because they assume the plastic will stick. When you poked at the hot plastic to test its softness, it wasn't sticky was it? Most problems with removing the pattern are because



of the shape, or because you painted the mold. Try it with nothing first, then use paste wax, furniture polish with silicone or silicone mold release agent.

**Dry your plaster molds** - Plaster contains water unless you force dry it in an oven or it is very old. It will still work OK as a pattern, but it will leave a big wet spot on your platen. This water can get sucked inside and cause corrosion on your platen or in your tank. Remove the plaster mold and wipe off the platen immediately after you use it. Do not use your Proto-Form machine to dry the plaster.

**Dry your plastic** - Some plastics such as ABS and Polycarbonate (Lexan) will absorb moisture from the air if not used quickly after purchase. This moisture turns into steam when heated and creates millions of tiny bubbles in the plastic. You can see them if its clear plastic or it can cause a rough surface if it is opaque.

These plastics may need to be dried at a lower temperature for several hours before you can use them. This should be done in an enclosed oven to heat from both sides, Do not use your Proto-Form machine to dry the plastic. contact your supplier for recommendations.

ABS is most commonly sold as a utility or "Wide Spec." grade which contains some recycled content. It usually forms OK if it is fresh, but it is more prone to the moisture problem. If your plastic bubbles or blisters, its not because the oven is too hot, its a plastic problem.

**Female Molds** - When you form over a male pattern, the thickness of the plastic tends to obscure some of the details. This works to our advantage if the pattern is less than perfect. Other times you want the maximum detail possible on the outside of the part, you can achieve this by forming into a female pattern. Your machine doesn't care one way or the other which type you use.

Female molds are typically made by first making a male pattern and then casting plaster or resin over it. You will have to drill some small holes into the cavity to evacuate it. In this case wherever you drill a hole it will leave a tiny bump on the outside of the part that can be easily sanded off.



## Epoxy Casting Resins

Made specifically for vacuum forming molds

### Source:

### Product:

BCC Products Co.  
2140 Earlywood Dr.  
Franklin, IN 46131  
(317) 736-4090

BC 8002 Kwik Kast II , Gray  
2 part Polyurethane 50/50 mix (black & white)  
Hi Temp 250 F. - 1 to 2 hr. cure time.  
low shrinkage. low viscosity, inexpensive.

This is my favorite resin for vacuum forming molds, its easy to mix and pour without bubbles, and its half the price of most others. Try this first

Smooth - On Inc.  
2000 St. John St.  
Easton, PA. 18042  
(610) 252-5800

A-30 Aluminum /Mineral filled casting resin  
C-1508 Rigid urethane casting resin

They also have flexible mold compounds. Call for nearest distributor.

Polytek Development Corp.  
55 Hilton Street  
Easton, PA. 18042  
(610) 559-8620

They offer many types of rigid and flexible molding and casting compounds including some that are formulated for vacuum forming patterns

They sell a 60 page molding and casting manual for \$10.00 that covers all of their products. They also offer lower cost trial units

Freeman Mfg.  
1101 Moore Rd.  
Avon, Ohio 44011  
1 (800) 321-8511

#925 Casting resin  
#935 Surface Coat  
#915 Laminating resin  
#310 Casting  
#332 Casting  
#408 Surface coat

They have a large catalog of Mold making and Pattern making supplies including mahogany and Jelutong pattern woods. Ask for nearest Distributor.